SIMULATION OF 6 PULSE GTO THYRISTOR CONVERTER AND HARMONICS ANALYSIS

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A thesis submitted in partially fulfillment of the requirement for the award of the degree of Bachelor of Electrical Engineering (Power System)

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DECLARATION

I declare that this thesis entitled “Simulation of 6 Pulse GTO Thyristor Converter and Harmonics Analysis” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

This project is about the simulation of 6 pulse GTO thyristor converter circuit and their harmonics analysis when the LC filter circuit is added to the system. Gate turn-off thyristor (GTO) are four-layer PNPN devices that act as switches, rectifiers, and voltage regulators. It is a fully controllable switches which can be turned on and off by their third lead, the GATE lead. Besides that, it is also high-power semiconductor device which make it suitable to be used in High-voltage Direct Current (HVDC) systems. The 6 pulse converter is also known as 3 phase fully controlled Full Wave Bridge Converter and can be functioned as a rectifier or an inverter. This project used OrCAD PSpice simulator to simulate the results for the analysis purpose. Computer simulation is a very economical and time effective approach to design the circuit since it is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works and if the simulation is successful, further action can be taken to prepare the hardware. It is also can be used in large scale system such as HVDC. The GTO thyristor model must be create since it is not included in the library of OrCAD PSpice. Using the GTO thyristor model, the 6 pulse GTO thyristor converter circuit will be created in OrCAD PSpice simulator. The evaluation and analysis of performance of simulation studies for a 6 pulse converter using PSPICE simulators with GTO thyristor as a control element is continue by adding the LC filter circuit to improve the performance of the converter circuit by reducing the harmful effects of the harmonics current. The harmonic for the circuit before and after adding the LC filter circuit is analyse and compared. The simulation results of DC output voltage is also will be compared to the mathematical calculation results by using graph. This contribution can be very useful particularly for the operation and maintenance personnel who can perform better with greater insight into the functioning of the complex system obtained through the model as developed.

ABSTRAK

Projek ini adalah mengenai simulasi litar penukar “6 pulse GTO thyristor” dan analisis harmonik mereka apabila litar penapis LC ditambah untuk sistem itu. “GTO thyristor” adalah empat lapisan PNPN yang boleh menjadi suis-suis, pelurus, dan pengatur-pengatur voltan. Ia adalah suis-suis terkawal sepenuhnya yang boleh dihidupkan dan dimatikan oleh kaki ketiga mereka, kaki GATE. Selain itu, ia peranti semikonduktor yang berkuasa tinggi dan membolehkan ia sesuai digunakan dalam sistem arus terus voltan tinggi (HVDC). Litar penukar “6 pulse” adalah turut dikenali sebagai 3 fasa “Full Wave Bridge Converter” terkawal sepenuhnya dan boleh berfungsi seperti satu pelurus atau satu penyongsang. Projek ini menggunakan pensimulasi OrCAD PSpice untuk mensimulasikan litar-litar untuk tujuan analisis. Simulasi berkomputer adalah satu kaedah yang sangat ekonomi dan pendekatan berkesan yang menjimatkan masa untuk merekabentuk litar kerana ia adalah satu cara memodelkan satu situasi sebenar atau secara hipotetikal menggunakan komputer supaya ia boleh dikaji untuk melihat bagaimana sistem itu bekerja dan sekiranya simulasi berjaya, tindakan lanjut boleh diambil untuk menyediakan perkakasan bagi menghasilkan produk sebenar. Ia juga boleh digunakan dalam sistem berskala besar seperti HVDC. Model “GTO thyristor” mesti dicipta terlebih dahulu kerana ia tidak terdapat dalam perpustakaan bagi perisian komputer OrCAD PSpice. Menggunakan model “GTO thyristor” yang dihasilkan, litar penukar “6 pulse GTO thyristor” akan dicipta dalam pensimulasi OrCAD PSpice. Penilaian dan analisis prestasi kajian simulasi untuk “6 pulse GTO thyristor” menggunakan simulator PSPICE yang menggunakan “GTO thyristor” sebagai satu unsur kawalan diteruskan dengan menambahkan litar penapis LC untuk meningkatkan prestasi bagi litar penukar dengan mengurangkan kesan-kesan berbahaya arus elektrik harmonik. Hasil simulasi bagi voltan output DC akan dibandingkan dengan pengiraan matematik menggunakan graf. Sumbangan ini sangat berguna terutama untuk kakitangan operasi dan penyelenggaraan yang boleh memajukan model ini dengan lebih baik.

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LIST OF SYMBOLS

W	-	Watt
I	-	Current
P	-	Power
V	-	Voltage
Ω	-	Ohm
H	-	Henry
F	-	Frequency
F	-	Farads
°	-	Degree
U	-	Commutation Overlap
A	-	Firing Angle

LIST OF ABBREVIATIONS

GTO	-	Gate-Turn-Off
SCR	-	Silicon Controlled Rectifier
HVDC	-	High Voltage Direct Current
AC	-	Alternating Current
DC	-	Direct Current
G1	-	Gate Circuit 1
G6	-	Gate Circuit 6
VSD	-	Variable Speed Drive
PFC	-	Power Factor Correction
UPS	-	Un-interruptible power supply
PS	-	Power System
PQ	-	Power Quality
TD	-	Time Delay

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CHAPTER 1

INTRODUCTION

1.1 Overview

In general, the electrical engineering field may be divided into three areas of specialization which is electronics, power and control. In the electronics, there is the study of semiconductor devices and circuits for the processing of information at low power level. For the power field, it deals with both rotating and static equipments for the generation, transmission and distribution systems to the loads. But the Control study is about the stability and response characteristics of the closed loop systems using feedback. This feedback can be used on either a continuous or sampled data basis to analyse the output of a system and make sure the system is stable.

The combination of power and electronics is called power electronics. This power electronics deals with the used of electronics for the control and conversion of large amounts electrical power. The power electronics equipment design involves the interactions between the sources, loads, utilities small signal electronic control circuits and power semiconductor devices.

Thyristor is the general named given to a family of power semiconductor switching devices. All of them is characterised by a bistable switching action depending upon PNPN regenerative feedback. The thyristor is normally has four or more layers and three or more junctions. They have similar characteristics to thyratron gas tube, see Figure 1.1. Thyratron is a type of gas filled tube used as a high energy electrical switch and controlled rectifier.

Figure 1.1 Thyratron gas tube.

The conventional thyristor known as Silicon Controlled Rectifier (SCR) is proposed by William Shockley in 1950 and championed by Moll and others at Bell Labs. It was developed in 1956 by power engineers led by Gordon Hall at General Electric (G.E.) and commercialized by G.E.'s Frank W. "Bill" Gutzwiller.

A gate turn-off thyristor (GTO) is a unique type of thyristor, a high-power semiconductor device. It is actually the replacement for the conventional thyristor, SCRs that are widely used in high power control circuits. SCRs are not fully controllable switches which are can only be turned ON and cannot be turned OFF. It can be switched ON by a gate signal, but even after the gate signal is not present, the thyristor remains in the ON-state until any turn-off condition occurs which can be the application of a reverse voltage to the terminals, or when the forward current falls below a certain threshold value known as the holding current. GTOs, as opposed to SCRs, are fully controllable switches which can be turned on and off by their third lead, the GATE

lead. This improvement of the thyristor family and their development has made it possible to manufacture a self commutated converter using the GTO thyristor for power electronics applications.

1.2 Background

This project is about the simulation of 6 pulse GTO thyristor converter circuit and their harmonics analysis after the LC filter circuit is added to the system. Gate turn-off thyristor (GTO) are four-layer PNPN devices that act as switches, rectifiers, and voltage regulators. It is a fully controllable switches which can be turned on and off by their third lead, the GATE lead. Besides that, it is also high-power semiconductor device which make it suitable to be used in High-voltage Direct Current (HVDC) systems. They are the most suitable for high-current, high speed switching applications, such as inverters and chopper circuits.

This GTO thyristor is used to overcome the disadvantage of the SCRs that has being used in various applications such as in power converter of HVDC transmission system and DC speed controller for DC motor application. The disadvantage of the SCR compared to the GTO thyristor is it can only be turn on with two conditions, that is by forward blocking state of the device or when positive gate current is applied to the gate. Besides that, it cannot be turned off automatically but only with natural commutation or forced commutation which means it is not self commutated compared to the GTO thyristor which is self commutated and can be used to supply power to the weak AC system and load only system while at the same time it is able to control reactive power from lead to lag to keep an ac bus voltage constant [1].

In Cambridge Advanced Learner's Dictionary, converter is defined as a machine or device that changes something into a different form. In engineering form, the electrical converter can be defined as converter that converts alternating current into

direct current or vice versa. For this project, the 6 pulse converter is used. The 6 pulse converter is also known as 3 phase fully controlled Full Wave Bridge Converter and can be functioned as a rectifier or an inverter. In this project, the 6 pulse GTO thyristor consist of 6 GTO thyristor triggered by the gate circuit G1 until G6.

The LC filter circuit consists of an inductor represented by the letter L, and a capacitor, represented by the letter C. It is an Electronic circuits which perform signal processing functions, specifically intended to remove unwanted signal components or enhance wanted ones. LC filter is normally used in the application circuit to reduce the harmful effects of the harmonics current.

This project used OrCAD PSpice simulator to simulate the results for the analysis purpose. Computer simulation is a very economical and time effective approach to design the circuit since it is an attempt to model a real-life or hypothetical situation on a computer so that it can be studied to see how the system works and if the simulation is successful, further action can be taken to prepare the hardware.

In this project, the GTO thyristor model with its operation circuit and gate circuit is created and simulate at different anode current using OrCAD PSpice simulator to analyse their switching characteristic. It is because there is no GTO thyristor model is included in the library of OrCAD PSpice. After that, this GTO thyristor model is implemented in designing the 6 pulse GTO thyristor converter circuit. The LC filter is used to reduce the harmful effects of the harmonics current to improve the circuit performance. Finally, the comparison of the simulation results of the DC output between before and after the LC filter circuit is added to the system is conducted for the harmonics analysis.

1.3 Objective

There are few objectives for this project; the first objective is to design the GTO thyristor model. The GTO thyristor model need to be design in this project since there is no GTO thyristor model is included in the library of OrCAD PSpice and this model will be simulate at different anode current using OrCAD PSpice simulator to analyse their switching characteristic. Besides that, the turn off time of the GTO thyristor also being analyse to proof that the higher percentage of the anode current used can improve the turn off time.

The second objective for this project is to design 6 pulse GTO thyristor converter circuit. In this stage, the GTO thyristor model that has been designed earlier is used to design the 6 pulse GTO thyristor converter circuit. The 6 pulse GTO thyristor consist of 6 GTO thyristor model triggered by the gate circuit G1 until G6. This 6 pulse GTO thyristor converter circuit is then simulate again at different firing angle using OrCAD PSpice simulator to analyse their function either as a rectifier or an inverter.

The third objective is to improve the design using LC filter circuit. The LC filter circuit is used to reduce the harmful effects of the harmonics current to improve the circuit performance of the 6 pulse GTO thyristor converter circuit. The Simulation using OrCAD PSpice simulator is again conducted to analyse their harmonics.

The fourth and the last objective is to do the harmonics analysis between before and after the LC filter circuit is added to the system. In this stage, all the simulation data from each of the design will be collected and compared for the analysis.

1.4 Scopes

Generally, this project concentrates on the development the circuit from the designing of the GTO thyristor model and their application circuit, 6 pulse GTO thyristor converter circuit until 6 pulse GTO thyristor converter with LC filter circuit. There are several simulations conducted for each of the circuit development for the analysis.

To make sure the development of the circuit and the analysis is completed, there is two scope or method used in this project which is the software and the analysis and comparison.

For the software, this project used **PSPICE – OrCAD Release 9.1** to design and simulate the circuit for the GTO thyristor model, 6 pulse GTO thyristor converter and 6 pulse GTO thyristor converter with LC filter.

For the analysis and comparison, the process started with the simulation results from all the circuit that being simulates using software is gathered and compared. Then, some of the mathematical calculation is conducted and compare with the simulation results. Lastly, the graph is prepared using all the data gathered from before for easy comparison and analysis.

1.5 Problem Statement

The advantage of high voltage direct current (HVDC) is the ability to transmit large amounts of power over long distances with lower capital costs and with lower losses than AC. Depending on voltage level and construction details, losses are quoted as about 3% per 1,000 kilometers. High-voltage direct current transmission allows efficient use of energy sources remote from load centers. The disadvantages of HVDC

are in conversion, switching and control. The required static inverters are expensive and have limited overload capacity. At smaller transmission distances the losses in the static inverters may be bigger than in an AC transmission line. The cost of the inverters may not be offset by reductions in line construction cost and lower line loss.

This disadvantage can be overcome by replacing all former mercury rectifiers worldwide with the GTO thyristor units. This is when the 6 pulse GTO thyristor converter with LC filter circuit can be used to make the HVDC transmission over short distance can be possible.

1.6 Thesis Organization

This thesis generally consists of five main chapters and each chapter will explain in details about this project. The first chapter is about the introduction of the project, it will elaborate on the overview, background, objective, scopes, problem statement and this thesis organization sub chapter.

The second main chapter is about the literature review related to this project. It will elaborate on the few paper of the previous researcher that the contents is related to this project. It can be used as information to conduct this project and to add more knowledge about the project.

The third chapter elaborates on the methodology for the simulation of 6 pulse GTO thyristor converter and harmonics analysis. It gives the review on how the GTO thyristor model is designed and analyse until the final circuit for 6 pulse GTO thyristor converter with LC filter is designed and analyse.

The fourth chapter will be displaying all the circuits and the simulation results obtained from the project. The discussion will be concentrate on the harmonics analysis before and after the LC filter circuit is added to the system.